Medieval Climatic Anomaly and Punctuated Cultural Evolution in Coastal Southern California

Author(s): L. Mark Raab and Daniel O. Larson
Source: *American Antiquity*, Vol. 62, No. 2 (Apr., 1997), pp. 319-336
Published by: Cambridge University Press
Stable URL: https://www.jstor.org/stable/282513
Accessed: 30-08-2018 22:05 UTC

MEDIEVAL CLIMATIC ANOMALY AND PUNCTUATED CULTURAL EVOLUTION IN COASTAL SOUTHERN CALIFORNIA

L. Mark Raab and Daniel O. Larson

Only in the last few years have high-resolution paleoclimatic data become available from coastal southern California. Recent research in the California Channel Islands, drawing on some of these data, attributes settlement disruptions, disease, and violence to maritime subsistence distress attendant to elevated sea temperatures in the period from A.D. 1150 to 1300. A broad range of paleoenvironmental, archaeological, and human osteological data suggest that these stress indicators are more convincingly correlated with severe late Holocene drought episodes during a portion of the medieval climatic anomaly (ca. A.D. 800 to 1400). Based on these data, cultural changes in coastal southern California, including violence, declining health, and emergent social complexity, are similar to events documented in the American Southwest. Cultural adaptations in both regions appear to have been responding to persistent drought conditions during the late Holocene.

Datos paleoclimáticos de alta resolución para la costa sur de California han aparecido solamente en los últimos años. Investigaciones recientes en Channel Islands, California, utilizan algunos de estos datos para atribuir disturbios, enfermedad, y violencia a los desastres en la subsistencia marítima ocasionados por altas temperaturas marinas en el periodo de 1150 a 1300 d.C. Un amplio rango de datos paleoambientales, arqueológicos, y osteológicos humanos sugieren que estos indicadores están más bien relacionados a episodios de sequía severa en el Holoceno tardío durante una porción de la Anomalía Climática Medieval (ca. 800 a 1400 d.C.). En base a estos datos, cambios culturales en la costa sur de California, incluyendo violencia, enfermedad, y complejidad social emergente, son eventos similares a aquéllos ocurridos en el Suroeste norteamericano. Adaptaciones culturales en ambas regiones parecen haber respondido a condiciones de sequía persistentes durante el Holoceno tardío.

The historical role of paleoenvironmental research in coastal southern California archaeology contrasts sharply with contiguous regions of North America. While studies of the American Southwest have long sought links between dynamic late Holocene cultural developments and environmental stresses, few archaeologists perceived coastal southern California in a similar light. This perception was fostered in part by a dearth of high-resolution paleoenvironmental data from the California coastal region. Just as importantly, coastal prehistory was dominated for more than a half-century by two interpretive themes that all but excluded environmental stress from theories of culture change. First, the natural environment was often characterized in terms of exceptionally high levels of subsistence stability and productivity. Second, culture change was attributed fundamentally to intrasocietal forces; particularly social and economic innovations that exploited the rich natural environment in progressively more productive ways. The dense, socially complex coastal populations that emerged in the last one or two millennia were viewed as the culmination of this happy interplay between cultural evolution and environment (e.g., King 1976, 1990; Landberg 1965; Moratto 1984:133–146; Raab 1996).

California archaeologists have long been interested in Holocene paleoenvironmental change (e.g., Carbone 1991; Glassow 1996; Glassow et al. 1988; Moratto et al. 1978), including the development of southern California's present Mediterranean climate. In general terms, it appears that this environmental regime was established during the last 4,000 to 6,000 years, when harsh (hot/dry) altithermal conditions were replaced by the modern pattern of warm, dry summers and cool, moist winters. The region's dominant chaparral and oak vegetation communities

L. Mark Raab ■ Department of Anthropology, California State University, Northridge, CA 91330
Daniel O. Larson ■ Department of Anthropology, California State University, Long Beach, CA 90840

American Antiquity, 62(2), 1997, pp. 319–336.

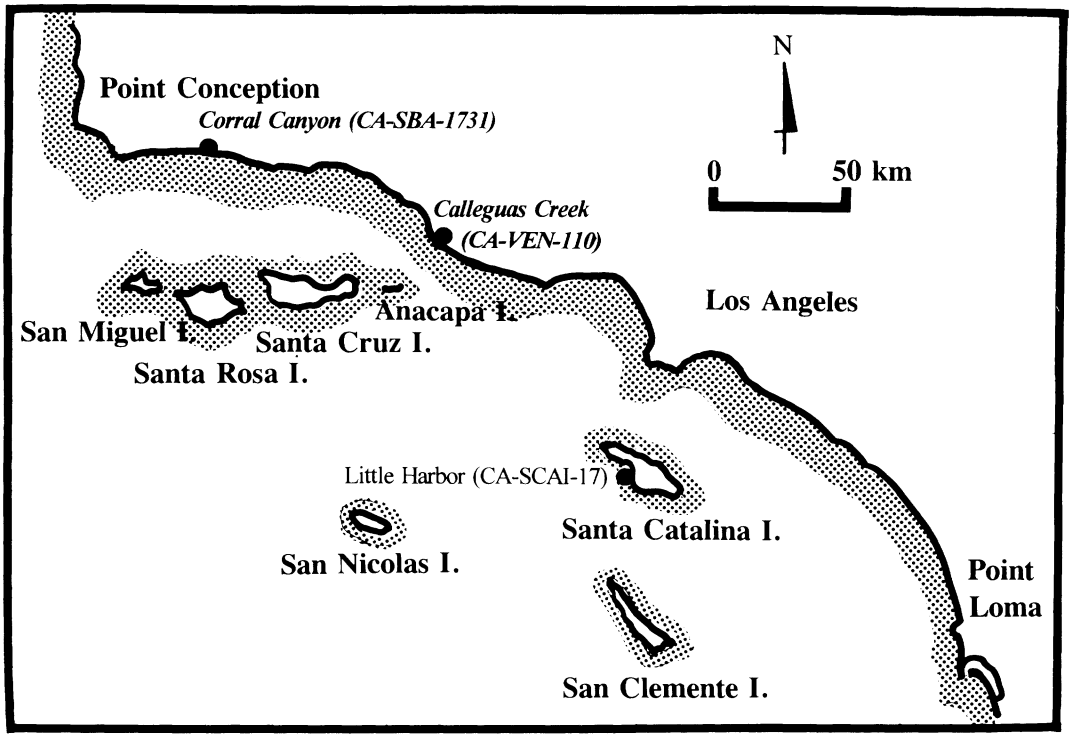

Figure 1. Southern California coastal region.

are thought to have emerged after this transition, stimulating an increasingly broad array of hunting-and-gathering strategies (Basgall 1987; Glassow 1996; Glassow et al. 1988; Jones 1996; McGuire and Hildebrandt 1994). For progressive cultural evolutionists, this transition was crucial to the development of complex social formations. Researchers suggested that in this environment some late Holocene California hunter-gatherers attained a level of subsistence productivity and social elaboration on par with simple agriculturists in other regions of the world, particularly where acorns were used (Bean and Lawton 1976). Although this notion of California "acorn agriculture" has been challenged (Basgall 1987; Raab 1996), it remains a popular theme, particularly in discussions aimed at public audiences (King 1994; Martin 1996).

The Chumash Indians are perhaps the premier example of the expansive possibilities of cultural evolution envisioned by many theorists for late Holocene southern California. Brief exploration of the Santa Barbara Channel area (Figure 1) by sixteenth-century Spanish explorers offered the first, albeit sketchy, accounts of Chumash Indian culture. More sustained contact with Europeans during the eighteenth and nineteenth centuries, particularly with the incorporation of the Chumash into the Spanish mission system, produced a substantially more detailed portrait of the Chumash (Johnson 1988). With the addition of archaeological and ethnographic research during this century, a body of information was compiled that now prompts many scholars to describe the Chumash as one of the most socially complex hunter-gatherer populations in native California, if not the world. Chumash groups frequently are described as chiefdoms in which hereditary elites exerted control over highly productive political economies based on labor specialization and redistribution of food surpluses (Arnold 1987, 1992; Erlandson 1994, 1996; Johnson 1988; King 1976, 1990; Kroeber 1976:550–573; Landberg 1965; Moratto 1984:126–146).

Although these reconstructions were assembled from an array of archaeological and ethnographic data that steadily expanded during this century, environmental factors were assigned a strikingly static role in prevailing models of Chumash cultural evolution. For instance, early luminaries such as Kroeber characterized much of California as a cornucopia of diverse, easily exploited foods, thus rendering California Indians as "perhaps the most omnivorous group of tribes on the continent" (Kroeber 1976:523–530). This circumstance followed from the notion that:

> the food resources of California were bountiful in their variety rather than in their overwhelming abundance along special lines. If one supply failed, there were a hundred others to fall back upon [Kroeber 1976:524].

Comments of this kind promoted the idea that many California groups were exempt from serious subsistence stress, except perhaps during the most extreme environmental perturbations. Coastal zones, such as that occupied by the Chumash, seemed particularly secure and bountiful, combining both marine and terrestrial resources. Kroeber (1976:551) comments that, "Marine life along the Chumash shores is exceptionally rich, the climate far famed, and every condition favored the unusual concentration of population among a people living directly upon nature." This view has proven remarkably durable. For example, fully half of Landberg's (1965) classic monograph on the Chumash deals with the natural resource abundance of the Santa Barbara Channel region. Similarly, recent characterizations of the Chumash by Fagan differ from Kroeber only to the extent of more explicitly correlating social complexity with environmental richness:

> The Chumash exploited a great variety of food resources ... "It may be said that for them, the entire day is a continuous meal," wrote one Spanish missionary marveling at the varied food resources enjoyed by the Chumash [Fagan 1995:252]. ... The Chumash achieved a level of social complexity that represents about the limit of such complexity possible without adopting agriculture. Like more complex hunter-gatherer societies elsewhere in North America ... they were able to achieve this elaboration because of unusually favorable environmental circumstances [Fagan 1995:253].

We have no quarrel with Fagan, whose comments are part of a textbook intended to represent prevailing thought. It is important to note, however, that these comments largely echo King's (1976, 1990, 1994) model of Chumash cultural evolution, widely cited over the last two decades. King (1976) identifies redistribution of diverse marine and terrestrial resources within an intervillage exchange network as the engine of culture change. The dynamics of this model fit squarely within the tradition of progressive social evolutionary theory described by Ames (1995:155–156):

> The elite-as-manager approach sees elites arising from the needs of complex divisions of labor for coordination of tasks, task groups, and information flow. In Service's (1975) classic formulation, emerging elites managed regional specialization in production through redistribution—leading to the formation of chiefdoms.

Something of this sort is clearly envisioned in King's model of Chumash regional exchange:

> The operation of the inter-village exchange system seems to have been essentially an expression of the profit motive on the individual level, and the operation of the law of supply and demand. Effects of the system were to produce a common resource base for a large area at the expense of much work [King 1976:296]. . . . By randomizing the effects of environmental variability with frequent interaction, the Chumash were able to use more of their resources; the degree of their interaction was a result of the high variability in the resources of the area. Their frequent use of [shell bead] money allowed them to average their many resources efficiently [King 1976:317].

King (1976, 1990) posits, at least implicitly, millennia of relatively stable and productive environmental conditions giving rise gradually to socioeconomic elaboration. Ethnographic data and contemporary environmental conditions outlined in his intervillage exchange model form the basis of this reconstruction. This feature of King's model, i.e., interpreting millennia of culture change on the basis of historic cultural patterns, has recently been criticized (see Arnold 1992; Arnold and O'Shea 1993). As we shall see below, King's model is also open to question for its uncritical use of historical environmental conditions as an analog of the prehistoric past. It must be recognized, of course, that King's model was formulated over two decades ago, when a paucity of paleoenvironmental data made it difficult to hypothesize about how prehistoric environmental conditions might have influenced Chumash cultural developments. Even so, King's model is now seriously dated in that it fails to reflect the high degree of dynamism documented by researchers for modern Mediterranean environments of the type found in coastal southern California (e.g., Davis 1995; Larson et al. 1994; McGinnies et al. 1968), much less the paleoenvironmental trends discussed here.

Although other investigators have taken paleoenvironmental trends into account in discussions of southern California coastal prehistory (e.g., Glassow 1996; Glassow et al. 1988; Jones 1996; Lambert and Walker 1991), Arnold posits specific connections between the emergence of a Chumash chiefdom on Santa Cruz Island (Figure 1) and a combination of late Holocene environmental stresses. According to this model, island subsistence economies were disrupted by elevated sea temperatures and severe regional droughts in the interval between about A.D. 1150 to 1300. Arnold (1992) argues that during this crisis, chiefs attained social power through control of resources and specialized labor required to manufacture marine shell beads and by trading these beads for mainland foodstuffs to buffer island food shortages.

If the "Kroeberian" scenario of environmental richness and subsistence security can be described as "hunter-gatherers-in-paradise," research such as Arnold's is fueling the emergence of models that can be characterized as "trouble-in-paradise." In the last decade, data from archaeological, paleoenvironmental, and human osteological studies have opened vigorous debate about the nature and timing of prehistoric culture change in coastal southern California (Fishman 1996). Recent research suggests the influence of paleoenvironmental forces powerful enough to stimulate new cultural adaptations; including a pace of change that was more "punctuated" than gradual and the ascent of elites wielding power better characterized as coercive than managerial (Arnold 1987, 1992, 1995; Arnold and O'Shea 1993; Raab 1995).

This reappraisal of Chumash cultural evolution represents a significant departure from the traditional conceptions of California prehistory examined earlier. In the present discussion, however, we draw attention to the paleoenvironmental data that are fostering new theoretical perspectives. In the remainder of this paper we examine the marine paleotemperature and paleoclimatic trends featured in Arnold's model of emergent Chumash social complexity. This examination shows that the observed archaeological indicators of stress, contrary to Arnold's conclusions, are more convincingly correlated with paleoclimatic trends than marine temperature conditions. These correlations also suggest that Santa Barbara Channel populations were responding to late Holocene climatic perturbations whose effects were felt far beyond southern California.

Marine Paleotemperature

As noted earlier, Arnold's work links two paleoenvironmental variables to culture change: elevated sea temperature and severe droughts (1987, 1992, 1995). She argues that both forces struck the Channel Islands between about A.D. 1150 to 1300, creating unusually stressful conditions for coastal hunter-fishers (Arnold 1992:70). But how did these two types of stress affect the extant cultural adaptations? This unresolved question is important because sea temperature and drought entail different kinds of stress and, therefore, seem likely to have required different adaptive responses by human populations. Unraveling the relative impact of sea temperature variation and drought is essential, if we are to have an accurate understanding of the role of paleoenvironmental forces in shaping culture change. In the present discussion it may be helpful to consider these forces separately before looking at their relative utility in accounting for key aspects of the archaeological record.

A number of researchers have drawn attention to the possible role of marine paleotemperature in determining the productivity of hunter-fisher subsistence economies of the southern California coast (Arnold 1987, 1992; Colten 1992, 1994; Glassow et al. 1988; Lambert and Walker 1991). This marine paleotemperature model features two important components. One of these components is an 8,000-year record of sea surface temperature (SST), based on analysis of temperature-sensitive radiolarian fossils in varved sea cores from the Santa Barbara Basin (Pisias 1978, 1979) (Figure 2a). A second component is the postulated effect of SST variation on kelp growth. Proponents of this model note that magnificent "kelp forests" of the genus *Macrocystis* (giant brown algae) support a prolific web of life that includes fish, sea mam-

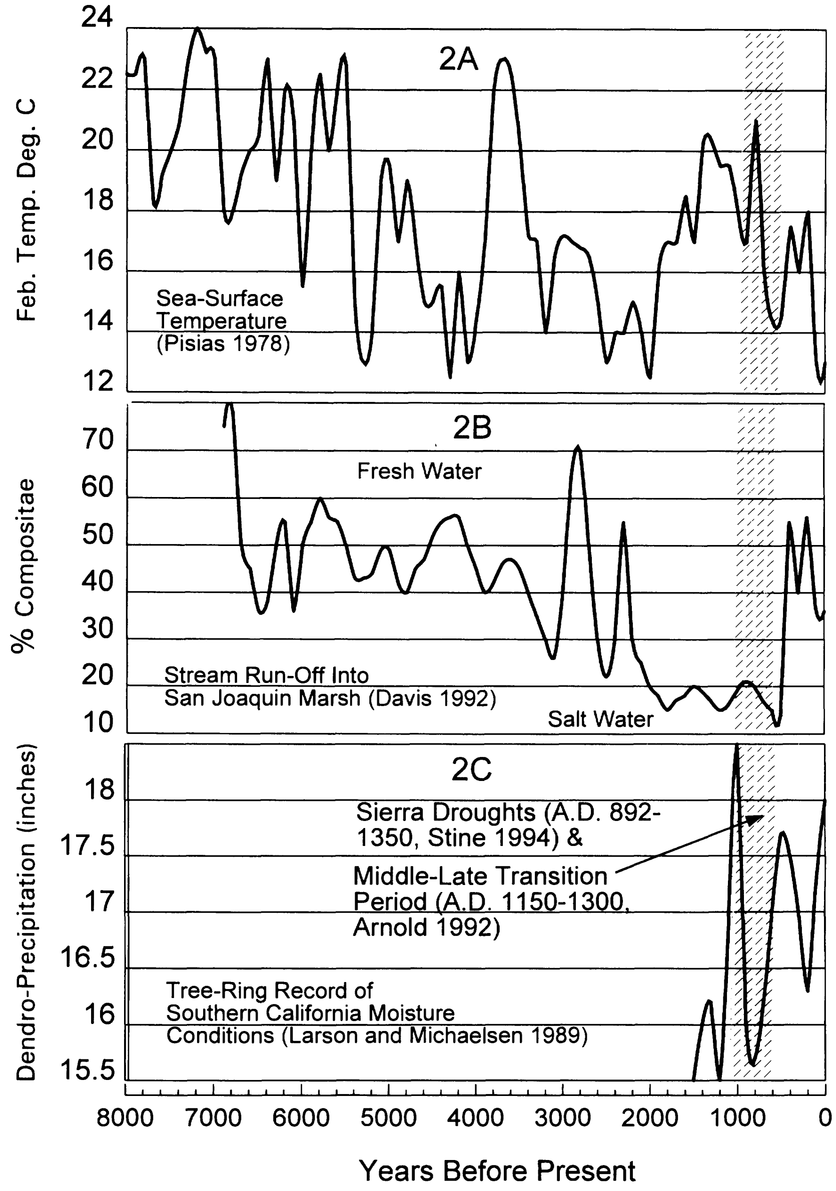

Figure 2. Comparison of sea temperature, moisture, and tree-ring records from southern California.

mals, and birds (Foster et al. 1983). These kelp bed species, frequently found in archaeological faunal assemblages, were of prime importance to coastal peoples, particularly inhabitants of the California Channel Islands, where terrestrial foods were comparatively scarce (Arnold 1992; Erlandson 1994; Glassow and Wilcoxon 1988; Glassow et al. 1988; Landberg 1965, 1975; Raab and Yatsko 1990).

Although many factors condition kelp abundance (Foster et al. 1983; Manley 1983; Tegner and Dayton 1987), the paleotemperature model emphasizes the fact that water temperatures above 20°C have a destructive impact on kelp beds (Arnold 1992; Colten 1992; Glassow et al. 1988). If we posit that warm-water periods in the past were hostile to the existence of kelp forests, we may then logically expect that human populations experienced depressed maritime subsistence conditions during such episodes.

Arnold (1992) believes that this kind of stress affected the inhabitants of Santa Cruz Island from about A.D. 1150 to 1300; a time interval defined by Arnold as the Transitional period or the Middle–Late Transition. By either name, this episode is described as a time of "environmental disruption" spurred by destruction of kelp beds, leading to "rapid social evolution" and the emergence of a chiefdom on Santa Cruz Island (Arnold 1992:66). As pointed out earlier, this argument contends that chiefs solidified their power through control of specialized labor and trade. Thus, elevated SST during the Transitional period plays the crucial role of a "kicker" that set cultural change on a trajectory of increasing socioeconomic complexity.

Paleoclimate

Only in the last decade has it become possible to examine prehistoric culture change on the southern California coast in relation to a range of relatively high-resolution paleoclimatic records. One of the most important of these is a 7,000-year pollen record based on a radiocarbon-calibrated, 687-cm core taken from the San Joaquin Marsh, located 7 km from the Pacific Ocean at the head of Newport Bay, Orange County, California (Davis 1992). This record (Figure 2b) reflects major shifts in effective moisture, particularly during the late Holocene. Davis (1992:92–93) notes that:

> The percentage pollen diagram is dominated by the "Other Compositae" and Chenopodiaceae-*Amaranthus* curves. Prior to ca. 3000 yr. B.P. Compositae dominates (40–70%), but from ca. 3000 to 500 yr. B.P. it is supplanted by Chenopodiaceae-*Amaranthus* (40–70%). Chenopodiaceae-*Amaranthus* pollen is produced by xerophytic plants in and around the marsh. . . . "Other Compositae" pollen is produced by many freshwater marsh plants . . . but is also abundant in California grassland. . . . Whether the source is grassland or marsh, a preponderance of Compositae pollen indicates vegetation more mesic than that characterized by Chenopodiaceae-*Amaranthus* dominance.

Since the San Joaquin Marsh exists between fresh- and saltwater conditions, decreased stream flow and lower discharge of springs feeding the marsh permitted saltwater incursion, beginning about 1,800 years B.P. (Figure 2b). These incursions are marked by relatively low pollen deposition and sedimentation rates and the presence of marine-estuarine organisms, such as dinoflagellates and foraminifera, and the pollen of salt marsh plants (Davis 1992:93). Conversely, periods of high stream flow are marked by comparatively rapid sedimentation rates, abundant palynomorphs, and high percentages of Compositae pollen (Davis 1992:92–98).

Tree-ring data have long been recognized as an important indicator of precipitation rates and other paleoclimatic phenomena, but only recently has information of this kind become available from coastal southern California. Larson and Michaelsen (1989) and Larson et al. (1994) have expanded our understanding of the late Holocene paleoclimate of the southern California coast with a 1,600-year tree-ring record. Commencing A.D. 400, this record (Figure 2c) was produced with data from trees located in the Transverse Ranges of central Santa Barbara County, California (ca. 140 km northwest of San Joaquin Marsh) and from San Gorgonio Mountain (ca. 200 km east of Santa Barbara). Larson and Michaelsen (1989:22–23) offer the following summary of regional dendro-precipitation trends:

> During the first 150 years of the reconstruction, A.D. 500 to 650, climatic conditions were characterized by moderately low precipitation levels. This period was followed by very low rainfall levels which lasted from A.D. 650 to 800. Extreme drought was experienced between A.D. 750 to 770. The succeeding 200 years, A.D. 800 to 1000, was a sustained high-interval unmatched in the entire 1600 year reconstruction . . . . Between A.D. 1100 to 1250 climatic conditions maintained a sustained low for a period of more than 150 years. The interval between A.D. 1120 to 1150 was particularly harsh.

Pollen and tree-ring records may record local conditions rather than trends that are representative of larger regions. The moisture trends reconstructed by Davis (1992) and Larson and Michaelsen (1989) are reinforced, however, by paleoclimatic evidence from other regions of California. Enzel et al. (1989) report that shallow lakes existed twice in the Silver Lake playa of the Mojave Desert during the late Holocene. They show that Silver Lake playa, located at the terminus of the Mojave River, receives only extreme floods, small to medium floods being filtered out by the Mojave River before they reach the terminal playa. A drill core from Silver Lake playa produced lacustrine sediments indicative of two lake-forming episodes; one at 3,620 ± 20 radiocarbon years B.P. and the other at 390 ± 90 radiocarbon years B.P. (Enzel et al. 1989:44–45). Enzel et al. conclude that these two episodes resulted from atmospheric forcing patterns that allowed unusually severe North Pacific storms to enter southern California. The second lake-forming episode at Silver Lake playa (390 ± 90 years B.P.) corresponds to a sharp upturn in moisture at San Joaquin Marsh and in the Sierra Nevada (Graumlich 1993). This upturn corresponds to the beginning of the Little Ice Age (ca. A.D. 1400 to 1870), a period marked by global cooling and generally increased moisture in the western United States (Graumlich 1993; Pielou 1991:308–309). The two Silver Lake flood episodes also correspond to intervals of comparatively high moisture at San Joaquin Marsh (Figure 2b).

Conversely, several indicators point to decreased moisture and/or elevated temperatures in the period between the Silver Lake Playa floods. Bristlecone tree rings in the eastern Sierra Nevada of California show decreased moisture accompanied by a sharp rise in temperature at about A.D. 1100 (Mehringer 1986:49–50). Based on analysis of fossil pack rat middens, Cole and Webb (1985) conclude that the eastern Mojave Desert was drier than at present between 500 and 2,000 years B.P. Similarly, Graumlich's (1993) tree-ring research in the southern Sierra Nevada points to warmer-than-present summer temperatures for the period of about A.D. 1100 to 1450. Graumlich (1993:254) argues that while this period experienced relatively severe moisture conditions, it was but one of many episodes of extended drought (> 20 years) during the last 1,000 years. Indeed, somewhat ominously, Graumlich (1993:255) notes that:

> Furthermore, results presented here indicate that high precipitation levels of the mid-20th century have occurred only three times in the previous 1000-year record. These results suggest that current drought in California is not an anomaly when considered in a long-term context and that agricultural, industrial, and urban systems that are dependent on water resources are highly vulnerable to disruption.

Some of the most dramatic evidence of climatic deterioration in this time frame is provided by Stine (1994), who obtained radiocarbon dates from the growth rings of trees drowned in Sierra Nevada lakes, streams, and marshes. Trees were able to invade these habitats during low-water stands, later to be killed by rising stream and lake levels. Radiocarbon dates show synchronous dry periods in four locations, indicating a regional pattern of drought. Stine (1994:549) reconstructs two "epic" droughts between about A.D. 892 to 1112 and A.D. 1209 to 1350; the first event lasting more than 220 years and the second more than 140 years. Stine (1994) also points out that these events fall within a time frame long recognized by paleoclimatologists as one of the most dynamic of the late Holocene. Variously dubbed the Medieval Warm period, Medieval Climatic Anomaly, and other terms (Graumlich 1993; Jones et al. 1996; Stine 1994), the period defined here as existing roughly from A.D. 800 to 1400 (see Jones et al. 1996) is correlated with a range of relatively extreme temperature/moisture conditions around the world, including persistent droughts in California.

In coastal southern California, the events described above appear to be reflected in moisture levels recorded at San Joaquin Marsh and in Larson and Michaelsen's tree-ring data (Figure 2b and 2c). Two specific points are worth noting here. First, the California coastal tree-ring and pollen records suggest fluctuating but generally declining moisture levels synchronous with the Medieval Climatic Anomaly, as outlined above (ca. A.D. 800–1400). Second, Arnold's Transitional period (ca. A.D. 1150–1300) falls near the end of this time span—i.e., within an interval documented by Stine (1994) and Graumlich (1993) as one of the most climatically rigorous of the last millennium. An important question remains, however. How are these trends correlated with patterns of culture change? The available data suggest that climatic deterioration during the Medieval Climatic Anomaly is correlated with relatively rapid and dramatic cultural changes in southern California and elsewhere, including settlement pattern shifts, declining health conditions, and the emergence of more complex social formations.

Discussion

Although Arnold (1992) and Colten (1992, 1994) identify disrupted settlement patterns and poor health conditions on the Channel Islands as indicators of stress imposed by elevated sea temperature and drought during the Transitional period, sea-temperature-induced subsistence failures appear to be identified as the primary source of stress. We argue that the stress indicators identified by Arnold and Colten are more convincingly correlated with moisture trends than marine subsistence problems. Several lines of evidence bolster this argument.

Our conclusions rest, in part, on an evaluation of the subsistence evidence, including Arnold's Santa Cruz Island data, undertaken elsewhere (Raab et al. 1995). While a detailed analysis of the pertinent marine subsistence data exceeds the scope of the present discussion, Raab et al. (1995) point out that there is little evidence of depressed marine food productivity during the Transitional period on Santa Cruz Island or at any other location in the region. In fact, evidence from Channel Islands and mainland archaeological sites contradicts the prediction that high sea temperatures are correlated with marine subsistence failures. In the Santa Barbara Channel, for instance, recent faunal data from site CA-SBA-1731 (Corral Canyon), the most intensively analyzed Transitional-period site to date on the mainland (Erlandson 1993:191), shows a pattern in which maritime subsistence productivity peaked during what was ostensibly the interval of highest water temperatures during the Transitional period (Raab et al. 1995:302). Located only 50 km from Santa Cruz Island, this site presents a serious challenge to the view that coastal economies of the Santa Barbara Channel region "crashed" during the Transitional period. Similarly, evidence from Santa Catalina and San Clemente islands, southern members of the Channel Islands, fails to show depressed subsistence conditions coincident with warm sea temperatures (Porcasi 1995; Raab et al. 1995). Recent research by Jones (1995) and Jones et al. (1996) on the central California coast also found little evidence of marine subsistence disruptions during the Transitional period.

Archaeological Stress Indicators

Two archaeological indicators of stress arising from the paleoenvironment are identified by Arnold: site occupational trends and the health status of coastal populations during the Transitional period. Arnold (1992:75–76) points to a widespread pattern of site abandonment on Santa Cruz Island during the Transitional period:

> Bead and microlith assemblages from surface collections and augering and testing programs indicate that several important Middle period quarries were abruptly abandoned at ca. A.D. 1200–1300, including sites SCRI-93, -127, -257, -394, -395, -396, -408, -409, -412, -414, -415, -417, -419, -474, and -495. Populations departed virtually simultaneously; sites with uninterrupted Middle to Late occupations are unexpectedly few in number across the island. Indeed, most Middle period localities are not reoccupied during the Late period, and few sites have generated ^{14}C dates or assemblages that are demonstrably from the A.D. 1200–1300 era.

Arnold (1992:76) also notes that detailed stratigraphic studies performed on Santa Cruz Island sites, including SCRI-191 (Cristy Ranch) and SCRI-240 (Prisoners Harbor), indicate that occupational hiatuses are present at these sites between about A.D. 1250–1300. A settlement pattern study by Petersen (1994) on Santa Cruz Island yields a similar pattern of occupational hiatus during the Transitional period.

High rates of disease and violence during the Transitional period in the Channel Islands are also cited by Arnold (1992:76) as indicators of stress:

> If human populations are stressed by subsistence deficiencies, then skeletal analyses may reveal increased incidence of cribra orbitalia (cranial osseous lesions associated with anemia; a form of porotic hyperostosis), Harris lines in long bones, dental hypoplasia (signs of disrupted growth due to acute nutritional stress or disease), or other indicators of subsistence stress. . . . Skeletal evidence may also be employed to identify competition for important resources. Recent studies suggest that records of violence through different eras of island prehistory vary, including rising incidences of depressed cranial bones suggestive of nonlethal clubbing that may coincide with warm-water cycles.

Returning to our earlier question, how are these stress indicators related to specific paleoenvironmental forces? We suggest that a closer examination of the patterns identified by Arnold reveals interesting results as regards the relative influence of sea temperature and drought on settlement patterns and health conditions during the Transitional period.

Settlement Patterns

To date, few archaeological studies in southern California have attempted to document the influence of drought on cultural patterns. Just the same, it is possible to glean a few insights into the probable impacts of drought on regional settlement patterns, economy, and social relations with existing archaeological and human osteological data.

True (1990) provides a case study, perhaps the most comprehensive to date, of prehistoric cultural patterning attributable to water sources along the southern California coast. Geological patterns, runoff rates and precipitation catchment size were used to estimate water availability within the San Luis Rey River drainage system of Northern San Diego County (True 1990:41–50). The distribution of archaeological sites of differing ages was examined in relation to these variables. True (1990:53–54) found that early Holocene settlement patterns (Pauma Complex, or Milling Stone Horizon) were associated with both perennial and ephemeral streams—a pattern suggesting that water was widely available during this time. On the other hand, sites occupied during the late Holocene (San Luis Rey I and San Luis Rey II) show a clear tendency to be associated with perennial water sources:

> For the central San Luis Rey River drainage, site distribution patterns suggest an increasing dependence on the consistently reliable water supplies. This patterning is seen as part of a shift from a relatively open, broad-based subsistence (Pauma Complex) to an increasingly structured sociocultural situation with defined territories, trespass rules, and probably an increased dependence on the acorn as a staple food (San Luis Rey II) [True 1990:57].

Although True (1990:57–58) considered climatic change as a cause of this pattern, he attributed shifting settlement patterns primarily to pressures arising from population growth. His insightful analysis was carried out, however, without the benefit of currently existing paleoclimatic records. In light of these records, the late Holocene settlement trends described by True are striking, for these trends reflect the sort of shifts that one would anticipate in an environment experiencing increasingly punishing moisture conditions.

Cross-cultural studies provide ample evidence that fishing, hunting, and gathering societies are quickly and significantly affected by shifts in environmental conditions, including moisture (Cashdan 1985, 1987, 1990; Colson 1979; de Garine and Harrison 1988; Dirks 1980; Halstead and O'Shea 1989; Hitchcock 1979; Maclachlan 1983; Spielmann 1986; Wiessner 1982). Coastal southern California consists of highly dynamic terrestrial ecosystems, where the effects of increased or decreased precipitation levels have profound impacts on the region's biota (see Larson et al. 1994). McGinnies et al. (1968) classify southern California as an arid zone, making a scarce water supply the most critical factor governing reproduction levels of plant and animal lifeforms. While the relationship between moisture and the abundance of plants and animals is complex, there can be little doubt that sustained low levels of precipitation have a profound impact on terrestrial ecosystems (Noy-Meir 1973), including depressed food resources for hunter-gatherers. Another source of stress under such conditions is a decline in discharge from springs and streams (Bowen 1982), which may dry up altogether. Water levels in estuaries and coastal marshes are significantly reduced as well (Bowen 1982; Deacon and Minckley 1974; Ford 1982). Increases in evapotranspiration significantly elevate the salinity and decrease the productivity of these sensitive habitats in a manner suggested, for example, by the pollen data from San Joaquin Marsh (Davis 1992).

If the late Holocene settlement dynamics described by True (1990) are consistent with the declining levels of moisture documented by recent paleoclimatic data, the occupational hiatuses documented by Arnold (1992:75–76) and Petersen (1994) for Santa Cruz Island may also be explicable in terms of these same dynamics. The Channel Islands are comparatively small precipitation catchments, a circumstance likely to make regional droughts particularly devastating to islanders. Intriguingly, the single example (RP-3) of 39 Santa Cruz Island archaeological sites identified by Petersen (1994:219–221) as containing a Transitional-period cultural component is a rock shelter thought to have been occupied because of its proximity to a perennial water source.

Testimony of the Dead

Some of the most important data on how human populations experienced the Transitional period is recorded in the skeletons of people who lived during this interval. A substantial body of information published during the last decade demonstrates that Transitional-period populations experienced some of the highest levels of malnutrition, disease, and violence contained in the entire Holocene osteological record. Surprisingly, the possible cultural and paleoenvironmental correlates of this record have not been extensively explored to date by archaeologists.

As we noted above, Arnold (1992:76) cites a high frequency of cribra orbitalia as a biological indicator of stressful conditions around the time of the Transitional period. This pattern is also pointed out by Colten (1994:201), who notes that:

> Physical anthropology provides evidence of nutritional stress and interpersonal violence just prior to the Transitional period, the time of prolonged warm water.... The health of people in the region generally declined prior to this period. Periosteal lesions, which are indicators of trauma, pathogens or nutritional deficiencies, become common. Cribra orbitalia, which indicates childhood anemia, was also common.

It is not clear in the discussions by Arnold (1992) and Colten (1994) whether cribra orbitalia (porotic hyperostosis) is attributed to pathogens or nutritional stress, although Arnold (1992:76) appears to attribute cribra to nutritional deficiencies. This is not an obscure point, however. Determining the probable etiology of cribra orbitalia in the Transitional period is of considerable significance in reconstructing paleoenvironmental conditions. A study of the incidence of cribra orbitalia in the prehistoric Channel Islands and adjacent mainland coast by Walker (1986) identifies two possible causes: chronic anemia resulting from iron-deficient foods and/or loss of iron through diarrheal disease during childhood. Walker (1986:346) argues that in the prehistoric Channel Islands, "High nutrient losses associated with diarrheal disease may often be more significant in the etiology of cribra orbitalia than a low intake of essential nutrients." He reaches this conclusion in part by noting that marine foods generally are rich in dietary iron (Walker 1986:346). Walker also observes that the incidence of cribra is inversely related to island size; i.e., the smallest islands reflect the highest incidence of this condition:

> In view of the sanitation problems the islanders are likely to have faced and the well-documented role of diarrheal infections in the etiology of childhood anemia, it seems likely that contamination of water sources with enteric bacteria contributed significantly to the porotic hyperostosis. The extensive drainage system of the Santa Barbara mainland provided Indians living there with numerous springs, streams, rivers, and sloughs. This abundant supply of alternative water sources would tend to decrease the risk of water contamination through heavy use. On the Channel Islands, in contrast, sources of drinking water are quite limited and many people would be forced to use a small number of freshwater springs. Aggregation of people around these heavily used springs would greatly increase the danger of water contamination [Walker 1986:351].

If Walker is correct, the causal link in this pattern is contaminated drinking water rather than limited dietary iron. This connection is provocative: if cribra orbitalia was particularly widespread during the Transitional period, does this mean that use of water sources intensified? Walker's (1986:351) scenario is couched in terms of the relatively greater scarcity of water on the Channel Islands than the mainland, but what would be the result if the number of water sources throughout the region were shrinking under the impact of climatic deterioration? The observed disease pattern, particularly as related to island size, seems more likely to be related to the availability of water than marine food items. This evidence takes on additional weight when added to the occupational hiatuses described by Arnold (1992) and Petersen (1994) for Santa Cruz Island and the mainland settlement patterns reconstructed by True (1990). All of these patterns could be viewed as logical correlates of Transitional-period settlement patterns reacting to shrinking water sources.

The incidence of other types of disease and violence yields another striking perspective on general health conditions in the coastal zone during the Transitional period. As one of the authors (Raab 1996) points out elsewhere, osteological data from the Santa Barbara Channel area appear to reflect gradually rising rates of disease and violence across the span of the Holocene. This pattern appears to be linked to long-term processes of subsistence intensification and resource depletion (Raab 1996; see also Glassow 1996). Despite this pattern, several skeletal indicators of health, including trauma attributable to interpersonal violence, peak sharply during the Transitional period.

In a study by Lambert (1993), Channel Islands cemetery populations, spanning perhaps 8,000 years, were compared in relation to skeletal indices of health. Burials were assigned to five sequential periods: Early Early period (EE), or from 6000 to 3500 B.C., Late Early period (LE), 3500 to 1400 B.C.; Early Middle period (EM), 1400 B.C. to A.D. 300; Late Middle period (LM), A.D. 300 to 1150, and Late period (L), A.D. 1150 to 1782 (Lambert 1993:913). These are admittedly broad slices of time, necessitated by the fact that some burials can only be assigned approximate ages. Even so, this timescale offers a useful means of examining long-term health trends.

While many factors involving health do not produce osseous evidence, skeletal indicators can offer insight into patterns of growth and development, disease and trauma. Lambert examined the frequency and extent of periosteal lesions and stature as health indicators. The utility of the former as a health indicator follows from the fact that:

> Periosteal lesions are osseous plaques that form on the external cortical surfaces when agents such as blood or pus lift the periosteum off the bone, stimulating the osteoblastic cells along the inner layer of the periosteum to lay down new bone.... This inflammatory response (periostitis) can result from infectious disease, nutritional deficiencies, or trauma. . . . On dry bone, periosteal lesions vary in appearance from discrete, superficial patches to nonspecific areas of swelling. . . . They most often occur on the shafts of the long bones (Lambert 1993:510).

Lambert (1993:511) also notes that, while several factors control stature, including genetic differences between populations and inbreeding, short stature is frequently associated with childhood disease and undernutrition:

> Based on our knowledge of the relation between stature and environment, and in the absence of evidence for circumstances in which inbreeding is likely to occur, temporal variation in femur length can be used to identify changes in food supply and in the disease load of a population.

Lambert's data are plotted in Figure 3. There, data series 1 and 2 show the frequency of periosteal lesions. Data series 1 shows the percentage of all burials with evidence of bone lesions, while series 2 displays the percentage of all tibiae with a least one periosteal lesion. Series 3 gauges the severity of periosteal lesions, based on a ratio of the length of lesions in relation to the length of the long bones on which they occur. Series 4 and 5 show long-term variation in male and female stature. This variation is expressed in the percent of individuals whose stature is above or below the average stature of males and females for all time periods ("0" line = mean stature for all populations).

Health also has an important behavioral dimension in rates of interpersonal violence. Walker (1989a) documents a pattern, referred to earlier by Arnold (1992:76), in which sublethal compression fractures of the skull occur with some frequency. The number of these injuries varies according to locality and time period, but about 19 percent of all crania examined from the Channel Islands exhibited one or more fractures (Walker 1989a:313). The frequency of these injuries, along with their characteristic size and form, indicates a pattern of behavior in which, typically, blows were delivered to the front and top of the skull. Most of these injuries show evidence of healing, and a number of crania reveal two or more fractures. Walker interprets this type of trauma as evidence of a style of combat intended to injure an opponent but not to inflict death (Walker 1989a:319).

Significantly, Walker (1989a:314 and 318) shows that these injuries increase over the Holocene, reaching their highest frequency in the Late Middle and Late periods, as defined by Lambert (1993). Figure 3 shows the mean percentage of burials with compression fractures by time period for populations of the northern Channel Islands and adjacent mainland coast (from Walker 1989a:314).

The trends plotted in Figure 3 should be approached with caution, since the frequency of some skeletal traits could be gauged only on the basis of a small number of burials—a more acute problem for the earlier time periods (Lambert 1993:513). The timescale in Figure 3 should also be viewed as fairly crude owing to the difficulty of assigning an exact age to some burials. Even with these caveats in mind, however, the trends in

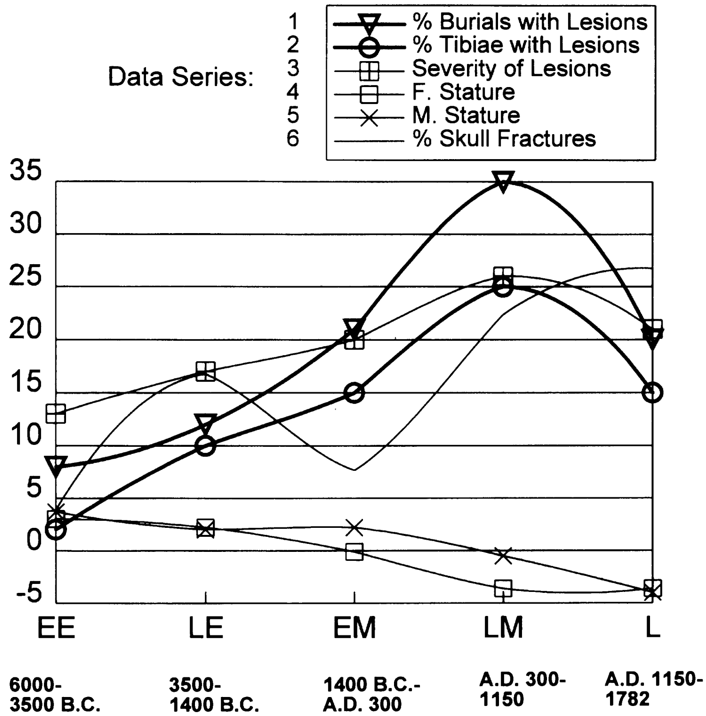

Figure 3. Changes in frequency and severity of periosteal lesions and stature and cranial trauma for Santa Barbara Channel populations (from Lambert 1993; Walker 1989a).

Figure 3 suggest significant, long-term changes in health conditions. For example, data series 1, 2, and 3 suggest that the frequency of bone lesions increased across the Holocene.

As stature drops below the mean stature line for the Holocene as a whole, the incidence of disease increases sharply. Incidence and severity of periosteal lesions peaks during the Late Middle period, or between about A.D. 300 to 1150, while stature continues to decline (data series 4 and 5). Lambert (1993:517), comparing the stature of early and late Holocene burial populations, points out that

> The total loss in average femur length is 2.8 centimeters (2.6 for males, 3.0 for females). Since femur length accounts for approximately 27 percent of a person's total height . . . this roughly translates into an average reduction in stature overall of about 10 cm between the earliest and latest populations.

Inbreeding is a conceivable factor in stature reduction among relatively isolated island populations. Nevertheless, the inverse relationship between disease and stature in Figure 3 implicates the former as a plausible cause of the latter. Interpersonal violence, as measured by compression fractures of the skull, also reaches a peak during the Late Middle and Late periods, or the time interval with the greatest incidence of disease and stature reduction.

Do these island trends have any significance for the mainland, or are the islands a special case? Did island populations face particularly difficult problems of environmental or social circumscription, problems unrelated to conditions on the mainland? These questions are answered by Walker and Lambert's (1989) study of the Calleguas Creek (CA-VEN-110) site on the Ventura County coast about 30 km from Santa Cruz Island. Radiocarbon dates indicate that use of the Calleguas Creek cemetery peaked in the A.D. 1200s, or during the Transitional period (Raab 1995). Walker and Lambert's (1989) study of dental hypoplasia, inflammatory bone legions, stature, and traumatic injuries at Calleguas Creek reveals some of the most severe health conditions observed in the study region for any time period (Walker 1989b). Walker and Lambert (1989:208) characterize the Calleguas Creek burial population in the following terms:

> Inflammatory bone lesions are common in the Ven-110 skeletal collection. One or more lesions were present in 24% of the discrete burials from the site.... Although most of these lesions are the result of osteoperiostitis, several burials also show evidence of endosteal involvement....
>
> The frequency of inflammatory lesions at VEN-110 is about the same as that at SCRI-110 [28 percent, Santa Cruz Island] and less than that at SCRI-83 [33 percent, Santa Cruz Island]. Lesions are much more common at these Middle and Late period sites than at the Early period site, SCRI-3 [12 percent, Santa Cruz Island]. . . .
>
> Although the number of VEN-110 burials with lesions is not particularly high, the affected individuals stand out because of the severity of their lesions and the high frequency of multiple lesions indicative of systemic infection.

Stature data yield equally compelling evidence of stress:

> The stature of the people buried at VEN-110 was smaller than that of all other sites we have studied except SBA-60 [Santa Barbara County]. . . . These data suggest that, at both sites, people were living under conditions that disrupted the growth and development of children [Walker and Lambert 1989:210].

Average height of the Calleguas Creek burial population (mean = 159.8 cm) is among the shortest known for all time periods in the study region (Walker and Lambert 1989:211; see also Lambert 1993).

Traumatic injuries also point to exceptionally high levels of lethal violence in the Calleguas Creek population:

> Traumatic injuries associated with warfare are common at VEN-110. About 10 percent of the adults have evidence of arrow wounds. One person had three arrow points embedded in the vertebral column and another individual had an arrow point in the pelvis. An additional person had a fractured arrow point encapsulated in reactive cancellous bone. Fragments of arrow points that shattered upon impact were found with two additional burials [Walker and Lambert 1989:210].

Lambert and Walker (1991:970) argue that this pattern of violence may have been instrumental in the adoption of the bow and arrow, which appears in the Santa Barbara Channel region sometime after about A.D. 500. If so, this early "arms race" underscores the great impact of violence during the Transitional period.

The trends described above cannot be attributed to paleoclimatic factors alone, since declining health appears to be a trans-Holocene phenomenon. Undoubtedly, a number of factors were involved in these changes. Lambert and Walker (1991:967–970), for instance, cite increasing population density during the Holocene as an important factor in the susceptibility of coastal populations to environmental stresses (see also Raab 1996). It is difficult, nonetheless, to escape the conclusion that dramatically declining health conditions during the Transitional period are correlated with evidence of climatic deterioration during the Medieval Climatic Anomaly.

A Transregional Perspective

Arnold's (1992) model is astute in citing environmental stress as a key agent of late Holocene culture change, but her focus on Santa Cruz Island does not adequately reflect the regional scope of settlement, health, and violence patterns associated with the Transitional period. Arnold's model may also obscure important long-term trends by focusing too narrowly on the Transitional period. Paleoclimatic data examined earlier suggest that moisture conditions began to deteriorate centuries before this period. Using Davis's (1992) pollen data, the longest continuous record of moisture conditions currently available in the study region, Figure 4 shows that deteriorating moisture conditions closely track a long-term decline in health; more so than the pattern of rising and falling sea temperatures (Figure 2a). These data suggest that if the stress responses observed in the Transitional period may be characterized as a "crash" in relation to settlement and subsistence conditions, these problems probably developed over a considerable period of time. Despite such a trend, it seems reasonable to hypothesize that late Holocene coastal southern California was affected by moisture deficits that were eventually severe enough to alter existing cultural adaptations.

Although Channel Islands populations may

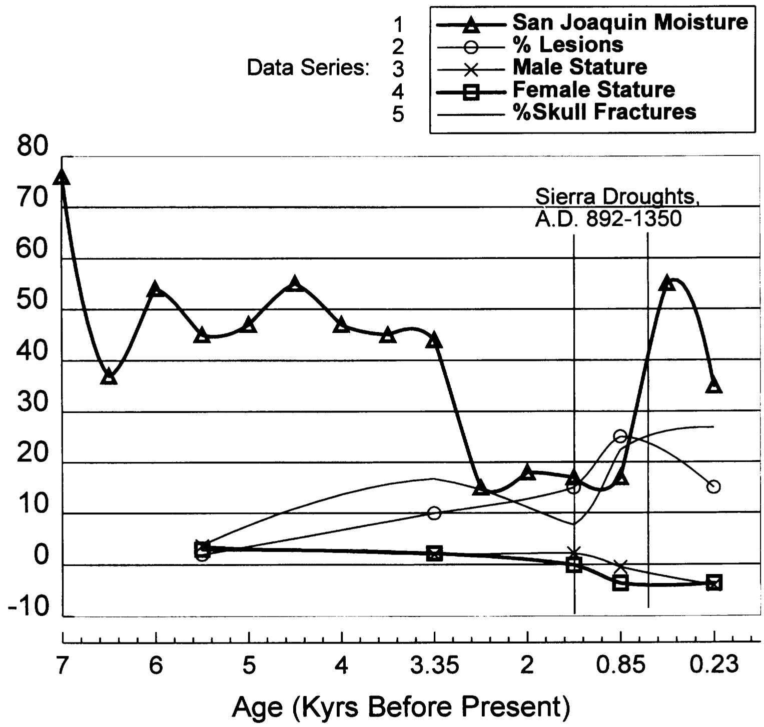

Figure 4. San Joaquin Marsh and Sierra moisture levels compared to health trends in the Santa Barbara Channel region (Davis 1992; Lambert 1993; Stine 1994; Walker 1989a).

have experienced more severe moisture conditions than the mainland during these episodes, it appears that coastal populations throughout the region were at increasing risk of disease, malnutrition, and violence brought about by shrinking supplies of water and terrestrial foods. Depressed terrestrial food supplies may help to explain why at least 76 percent of the animal protein consumed during the Transitional-period occupation of the mainland Corral Canyon site (CA-SBA-1731) was obtained from marine sources (Erlandson 1993:191). These resources, particularly in conjunction with surviving water sources in coastal streams, may have attracted populations to coastal refugia (Jones et al. 1996; Raab 1995). In this connection, there may be other interesting hints of shifting settlement patterns on the mainland during the Transitional period, including the results of research on late prehistoric archaeological sites near the Ballona Lagoon, coastal Los Angeles County, California. Commenting on the distribution of sites on bluff tops overlooking Ballona Creek at approximately A.D. 1000, Altschul et al. (1992:366–367) note, "The bluff top, occupied for the proceeding 2,000 years, was virtually abandoned, with settlement being established at the base of the bluffs along Centinela Creek and north of Ballona Creek." Moreover, Altschul et al. (1992:367) comment that:

> The Hughes site [CA-LAN-59] is intriguing for it is the only site on the bluff top that has a Late period occupation. This site is located near Centinela Creek, which would have provided the site with nearby potable water.

At least some of the paleoenvironmental trends hypothesized for late Holocene coastal southern California, such as climatic deterioration, involve forces that logically could have been felt by cultural systems over a wide area of the western United States. While we cannot undertake a comprehensive review of the evidence for such connections here (see Jones et al. 1996; Larson et al. 1996), the California data reveal striking similarities to recent research from the American Southwest.

Models employing climatic stress have always enjoyed an inherent plausibility in the arid American Southwest, where many find it easy to imagine agriculturalists living a precarious existence. On the other hand, few have been inclined to view California coastal hunter-gatherers at risk from similar environmental perturbations; particularly given the legacy of theory and research outlined earlier. And yet, recent research suggests that both coastal southern California and the Southwest were subjected to powerful environmental stresses during the late Holocene. Does this mean that culture change in either region can be explained in some simple, environmentally deterministic way or that southern California should now be viewed, in paleoenvironmental terms, as an extension of the American Southwest? Not at all. Culture change in these two regions clearly involved a wide range of disparate factors, including differences of demography, climate, subsistence resources, technology, social organization, and long-term patterns of subsistence intensification. Even under the impact of similar paleoenvironmental stresses, it seems highly unlikely that cultural systems in coastal California and the Southwest would have responded in precisely similar ways. All these differences acknowledged, it nonetheless appears that late Holocene climatic variability and droughts stressed, and in some instances exceeded, the adaptive capabilities of both agricultural and hunter-gatherer cultural systems of California and the Southwest (see also Jones et al. 1996; Larson et al. 1996). If so, stresses of paleoenvironmental origin may have been a significant factor in bringing about the dynamic sequences of culture change recorded in many regions of late Holocene western North America.

Researchers in both California and the Southwest have targeted the thirteenth century as particularly "turbulent," "unsettled" and marked by rapid culture change in the wake of highly variable and frequently severe moisture conditions (e.g., Arnold 1992; Lambert and Walker 1991; Larson et al. 1996; Lipe 1995). In the Southwest, the impact of the "Great Drought" (Douglass 1929), ca. A.D. 1270 to 1300, has been debated for decades as a cause of the abandonment of Pueblo communities (Cordell 1984:304–325; Larson et al. 1996). While this debate will no doubt continue, a number of researchers are convinced that climatic instability and drought during the Medieval era, along with a number of other factors, dramatically transformed some regions of the Southwest. It is during this same time interval that the California paleoenvironmental record reflects severe moisture conditions, i.e., between about A.D. 800 to 1400 (the Medieval Climatic Anomaly as defined here), a span also encompassing Arnold's Transitional period (A.D. 1150 to 1300). Much like the Transitional-period conditions in California reviewed earlier, Lipe (1995) points to widespread subsistence crises, settlement dislocations, deteriorating health conditions, and high levels of violence peaking among Puebloan societies during the A.D. 1200s. Moreover, as Lipe (1995) documents, a number of southwestern researchers theorize that new social hierarchies emerged within some Puebloan groups at this time in an attempt to cope with these stressful conditions. Although employing causal scenarios based on quite different environmental conditions and cultural systems, California researchers envision similar stresses as a "kicker" in stimulating the emergence of social ranking among the Chumash in the same time frame (Arnold 1992; Lambert and Walker 1991; Raab 1995).

We believe that the data summarized above warrant rethinking certain aspects of coastal California prehistory. First, models of culture change that posit coastal southern California as an essentially unchanging and productive environment should be replaced with hypotheses based on a more informed appraisal of paleoenvironments and their likely cultural impacts. Second, the de facto scenarios of hunting-and-gathering-in-paradise that have prevailed since early in the century are now clearly out of step with recent research in paleoeclimatology, archaeology, and biological anthropology. Future research in California might proceed along five lines: (1) analysis of coastal and island marine subsistence yields spanning the Transitional period to better understand the relative contributions of marine and terrestrial food supplies; (2) examination of bioarchaeological data for patterns of pathology during wet and dry periods; (3) examination of relationships between settlement patterns and water sources on the islands and mainland during wet and dry periods; (5) development of additional paleoenvironmental records such as pollen studies on the Channel Islands and mainland.

Not only would research along these lines prove informative in terms of regional and North American prehistory, it would allow coastal southern California to further develop its considerable potential for the study of prehistoric culture change. In this discussion we have only touched on two aspects of this potential: (1) California can contribute to larger discussions of how long-term subsistence intensification processes may have been affected by environmental change, with important consequences for understanding population growth, socioeconomic elaboration, and health trends (Glassow 1996; Raab 1996), and (2) the Chumash data can help to illuminate the role that paleoenvironmental factors may have played in emergent social complexity among foraging societies. This would be an important contribution to understanding the appearance of social formations that fall on the spectrum of complexity between egalitarian hunter-gatherers on the one hand and strongly ranked chiefdoms and states on the other (Arnold 1995).

Acknowledgments. We offer particular thanks to Lynne Goldstein, editor of *American Antiquity*, for her assistance and encouragement in preparing this paper. In addition, we acknowledge the anonymous reviewers, who helped to improve the paper's content and organization. Although the authors alone are responsible for any errors of fact or interpretation in this paper, several persons played a particularly important role in shaping our thinking. To these persons we offer our thanks: Jeffrey Altschul, Matthew Boxt, Katherine Bradford, William Howard, Terry Jones, Scott Stine, Philip Walker, and Andrew Yatsko.

References Cited

Ames, K. M.
1995 Chiefly Power and Household Production on the Northwest Coast. In *Foundations of Social Inequality*, edited by T. D. Price and G. M. Feinman, pp. 155–187. Plenum Press, New York.

Arnold, J. E.
1987 *Craft Specialization in the Prehistoric Channel Islands, California*. Publications in Anthropology No. 18. University of California, Berkeley.
1992 Complex Hunter-Gatherer-Fishers of Prehistoric California: Chiefs, Specialists and Maritime Adaptations of the Channel Islands. *American Antiquity* 57:60–84.
1995 Social Inequality, Marginalization, and Economic Process. In *Foundations of Social Inequality*, edited by T. D. Price and G. M. Feinman, pp. 87–103. Plenum Press, New York.

Arnold, J. E., and J. M. O'Shea
1993 Review of "The Evolution of Chumash Society: A Comparative Study of Artifacts Used in Social System Maintenance in the Santa Barbara Channel Region before A.D. 1804" by C. D. King. *American Antiquity* 58:770.

Altschul, J. H., J. A. Homburg, and R. S. Ciolek-Torrello
1992 Prehistoric Subsistence and Settlement in the Ballona. In *Life in the Ballona: Archaeological Investigations at the Admiralty Site (CA-LAN-47) and the Channel Gateway Site (CA-LAN-1596-h)*, pp. 365–376. Technical Series No. 33. Statistical Research, Tucson, Arizona.

Basgall, M. E.
1987 Resource Intensification among Hunter-Gatherers: Acorn Economies in Prehistoric California. *Research in Economic Anthropology* 9:21–52.

Bean, L. J., and H. Lawton
1976 Some Explanations of the Rise of Cultural Complexity in Native California with Comments on Proto-Agriculture and Agriculture. In *Native Californians: A Theoretical Perspective*, edited by L. J. Bean and T. C. Blackburn, pp. 19–48. Ballena Press, Ramona, California.

Bowen, R.
1982 *Surface Water*. Applied Science, London.

Carbone, L. A.
1991 Early Holocene Environments and Paleoecological Contexts on the Central and Southern California Coast. In *Hunter-Gatherers of Early Holocene Coastal California*, edited by J. M. Erlandson and R. H. Colten, pp. 11–17. Perspectives in California Archaeology, vol. 1. Institute of Archaeology, University of California, Los Angeles.

Cashdan, E.
1985 Coping with Risk: Reciprocity among the Basarwa of Northern Botswana. *Man* 20:454–474.
1987 Trade and Its Origins on the Boteti River, Botswana. *Journal of Anthropological Research* 43:121–138.
1990 Information Costs and Customary prices. In *Risk and Uncertainty in Tribal and Peasant Economies*, edited by E. Cashdan, pp. 259—278. Westview Press, Boulder.

Cole, K. L., and R. H. Webb
1985 Late Holocene Vegetation Changes in Greenwater Valley, Mojave Desert, California. *Quaternary Research* 23:227–235.

Colson, E.
1979 In Good Years and in Bad: Food Strategies of Self-Reliant Societies. *Journal of Anthropological Research* 35:18–29.

Colten, R. H.
1992 Preliminary Analysis of Faunal Remains from Four Sites on Santa Cruz Island. In *Proceedings of the Society for California Archaeology* 5:247–267. San Diego, California.
1994 Prehistoric Animal Exploitation, Environmental Change, and Emergent Complexity on Santa Cruz Island, California. In *The Fourth California Islands Symposium: Update on the Status of Resources*, edited by W. L. Halvorson and G. J. Maender, pp. 201–214. Santa Barbara Museum of Natural History, Santa Barbara, California.

Cordell, L. S.
1984 *Prehistory of the Southwest*. Academic Press, New York.

Davis, M.
1995 Los Angeles after the Storm: The Dialectic of Ordinary Disaster. *Antipode* 27:221–241.

Davis, O. K.
1992 Rapid Climatic Change in Coastal Southern California Inferred from Pollen Analysis of San Joaquin Marsh. *Quaternary Research* 37:89–100.

Deacon, J. E., and W. L. Minckley
1974 Desert Fishes. In *Desert Biology: Special Topics on*

the Physical and Biological Aspects of Arid Regions, pp. 385–488. Academic Press, New York.
de Garine, I., and G. A. Harrison
1988 *Coping with Uncertainty in Food Supply*. Clarendon Press, Oxford.
Dirks, R.
1980 Social Responses during Severe Food Shortage and Famine. *Current Anthropology* 21:21–44.
Douglass, A. E.
1929 The Secret of the Southwest Solved by Talkative Tree-rings. *National Geographic* 54:737–770.
Enzel, Y., D. R. Cayan, R. Y. Anderson, and S. G. Wells
1989 Atmospheric Circulation During Holocene Lake Stands in the Mojave Desert: Evidence of Regional Climate Change. *Nature* 341:44–47.
Erlandson, J. M.
1993 Summary and Conclusions. In *Archaeological Investigations at CA-SBA-1731: A Transitional Middle-to-Late Period Site on the Santa Barbara Channel*, edited by J. L. Gerber, pp. 187–196. Dames and Moore. Report prepared for Exxon Company, Goleta, California. Copies available from Dames and Moore, Santa Barbara, California.
1994 *Early Hunter-Gatherers of the California Coast*. Plenum Press, New York.
1997 The Evolution of Maritime Societies on the California Coast. In *Western North American Maritime Prehistory*, edited by A. R. Blukis-Onat. Simon Fraser University Press, Burnaby, British Columbia, in press.
Fagan, B. M.
1995 *Ancient North America*. Thames and Hudson, New York.
Fishman, J.
1996 California Social Climbers: Low Water Prompts High Status. *Science* 272:811–812.
Ford, M. J.
1982 *The Changing Climate: Responses of the Natural Fauna and Flora*. George, Allen and Unwin, Boston.
Foster, M. S., J. W. Carter, and D. R. Shiel
1983 The Ecology of Kelp Communities. In *The Effects of Waste Disposal on Kelp Communities*, edited by W. Bascom, pp. 53–69. Southern California Coastal Water Research Project, and the Institute of Marine Resources, University of California, La Jolla, California.
Glassow, M. A.
1996 *Purisimeño Chumash Prehistory*. Harcourt Brace, New York.
Glassow, M. A., and L. R. Wilcoxon
1988 Coastal Adaptations near Point Conception, with Particular Regard for Shellfish Exploitation. *American Antiquity* 53:36–51.
Glassow, M. A., L. R. Wilcoxon, and J. M. Erlandson
1988 Cultural and Environmental Change during the Early Period of Santa Barbara Channel Prehistory. In *The Archaeology of Prehistoric Coastlines*, edited by G. N. Bailey and J. Parkington, pp. 64–77. Cambridge University Press, Cambridge.
Graumlich, L. J.
1993 A 1000-Year Record of Temperature and Precipitation in the Sierra Nevada. *Quaternary Research* 39:249–255.
Halstead, P., and J. O'Shea (editors)
1989 *Bad Year Economics: Cultural Responses to Risk and Uncertainty*. Cambridge University Press, Cambridge.
Hitchcock, R. K.
1979 The Traditional Response to Drought in Botswana. In *Proceedings of the Symposium on Drought in Botswana*, edited by M. T. Hinchey, pp. 91–97. Clark University Press, Hanover, New Hampshire.
Johnson, J. R.
1988 *Chumash Social Organization: An Ethnohistoric Perspective*. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Santa Barbara.
Jones, T. L.
1995 *Transitions in Prehistoric Diet, Mobility, Exchange, and Social Organization along California's Big Sur Coast*. Unpublished Ph.D. dissertation. Department of Anthropology, University of California, Davis.
1996 Mortars, Pestles, and Division of Labor in Prehistoric California: A View from Big Sur. *American Antiquity* 61:243–264.
Jones, T. L., G. M. Brown, D. J. Kennett, J. L. McVickar, L. M. Raab, G. Spaulding, P. L. Walker, and A. York
1996 The Medieval Climatic Anomaly in Western North American Prehistory. Manuscript on file, Northridge Center for Public Archaeology, California State University, Northridge.
King, C. D.
1976 Chumash Inter-Village Economic Exchange. In *Native Californians: A Theoretical Perspective*, edited by L. J. Bean and T. C. Blackburn, pp. 288–318. Ballena Press, Ramona, California.
1990 *The Evolution of Chumash Society: A Comparative Study of Artifacts Used in Social System Maintenance in the Santa Barbara Channel Region before A.D. 1804*. Garland, New York.
1994 *Prehistoric Native American Cultural Sites in the Santa Monica Mountains*. Report prepared for the Santa Monica Mountains and Seashore Foundation and National Park Service, Western Region. Report on file with the Santa Monica Mountains National Recreation Area, Agoura Hills, California.
Kroeber, A. L.
1976 *Handbook of the Indians of California*. Reprint. Originally published in 1925 as Bulletin No. 78 of the Bureau of American Ethnology, Smithsonian Institution, Washington, D.C. Dover Books, New York.
Lambert, P. M.
1993 Health in Prehistoric Populations of the Santa Barbara Channel Islands. *American Antiquity* 58:509–522.
Lambert, P. M., and P. L. Walker
1991 Physical Anthropological Evidence for the Evolution of Social Complexity in Coastal Southern California. *Antiquity* 65:963–973.
Landberg, L.
1965 The Chumash Indians of Southern California. *Southwest Museum Papers 19*. Los Angeles.
1975 Fishing effort in the Aboriginal Fisheries of the Santa Barbara Region, California: An Ethnohistorical Appraisal. In *Maritime Adaptations of the Pacific*, edited by R. W. Casteel and G. T. Quimby, pp. 145–170. Aldine, Chicago.
Larson, D. O., J. R. Johnson, and J. C. Michaelsen
1994 Missionization among the Coastal Chumash of Central California: A Study of Risk Minimization Strategies. *American Anthropologist* 96:263–299.
Larson, D. O., and J. Michaelsen
1989 Climatic Variability: A Compounding Factor Causing Culture Change among Prehistoric Coastal Populations. Unpublished manuscript on file, Department of Anthropology, California State University, Long Beach.
Larson, D. O., H. Neff, D. A. Graybill, J. Michaelsen, and E. Ambos

1996 Risk, Climatic Variability, and the Study of Southwestern Prehistory: An Evolutionary Perspective. *American Antiquity* 61:217–241.

Lipe, W. D.
1995 The Depopulation of the Northern San Juan: Conditions in the Turbulent 1200s. *Journal of Anthropological Archaeology* 14:143–169.

McGinnies, W. G., B. J. Golman, and P. Paylore (editors)
1968 *Deserts of the World: An Appraisal of Research into Their Physical and Biological Environments.* University of Arizona Press, Tucson.

McGuire, K. R., and W. R. Hildebrandt
1994 The Possibilities of Women and Men: Gender and the California Milling Stone Horizon. *Journal of California and Great Basin Anthropology* 16:41–59.

Maclachlan, M. D.
1983 *Why They Did Not Starve: Biocultural Adaptation in a South Indian village.* Institute for the Study of Human Issues, Philadelphia.

Manley, S. L.
1983 The Physiological Basis of Kelp Growth. In *The Effects of Waste Disposal on Kelp Communities*, edited by W. Bascom, pp. 38–52. Southern California Coastal Water Research Project, and the Institute of Marine Resources, University of California, La Jolla.

Martin, G.
1996 Keepers of the Oaks. *Discovery* 17:44–50.

Mehringer, P. J.
1986 Prehistoric Environments. In *Handbook of North American Indians*, vol. 11, edited by W. L. D'Azevedo, pp. 45–50. Smithsonian Institution, Washington, D.C.

Moratto, M. J.
1984 *California Archaeology*. Academic Press, New York.

Moratto, M. J., T. F. King, and W. B. Woolfenden
1978 Archaeology and California's Climate. *Journal of California Anthropology* 5:147–161.

Noy-Meir, I.
1973 Desert Ecosystems: Environment and Producers. *Annual Review of Ecology and Systematics* 4:25–51.

Peterson, R. R.
1994 Archaeological Settlement Dynamics on the South Side of Santa Cruz Island. In *The Fourth California Islands Symposium: Update on the Status of Resources*, edited by W. L. Halvorson and G. J. Maender, pp. 215–222. Santa Barbara Museum of Natural History, Santa Barbara, California.

Pielou, E. C.
1991 *After the Ice Age*. University of Chicago Press, Chicago.

Pisias, N. G.
1978 Paleoceanography of the Santa Barbara Basin during the Last 8000 Years. *Quaternary Research* 10:366–384.
1979 Model for Paleoceanographic Reconstructions of the California Current for the Last 8,000 Years. *Quaternary Research* 11:373–386.

Porcasi, J. F.
1995 *Identification and Analysis of Mammalian and Avian Remains Recovered from 1994 Excavation at Eel Point, San Clemente Island, California.* Unpublished Master's thesis, Department of Anthropology, California State University, Northridge.

Raab, L. M.
1995 *The Dead at Calleguas Creek: A Study of Punctuated Cultural Evolution During the Middle-Late Period Transition in Southern California.* Prepared for Environmental Division, Naval Air Weapons Station, Point Mugu, California. On file at Center for Public Archaeology, California State University, Northridge.
1996 Debating Prehistory in Coastal Southern California: Political Economy vs. Resource Intensification. *Journal of California and Great Basin Anthropology* 18:64–80.

Raab, L. M., K. Bradford, J. F. Porcasi, and W. J. Howard
1995 Return to Little Harbor, Santa Catalina Island, California: A Critique of the Marine Paleotemperature Model. *American Antiquity* 60:287–308.

Raab, L. M., and A. Yatsko
1990 Prehistoric Human Ecology of *Quinquina*, A Research Design for Archaeological Studies of San Clemente Island, Southern California. *Pacific Coast Archaeological Society Quarterly* 26:10–37.

Service, E. R.
1975 *Origins of the State and Civilization, The Process of Cultural Evolution.* W. W. Norton, New York.

Spielmann, K. A.
1986 Interdependence among Egalitarian Societies. *Journal of Anthropological Archaeology* 5:279–312.

Stine, S.
1994 Extreme and Persistent Drought in California and Patagonia during Mediaeval Time. *Nature* 369:546–549.

Tegner, M. J., and P. K. Dayton
1987 El Niño Effects on Southern California Kelp Forest Communities. *Advances in Ecological Research* 17:243–279.

True, D. L.
1990 Site Locations and Water Supply: A Perspective from Northern San Diego County, California. *New World Archaeology* 4:37–60.

Walker, P. L.
1986 Porotic Hyperostosis in a Marine-Dependent California Indian Population. *American Journal of Physical Anthropology* 69:345–354.
1989a Cranial Injuries as Evidence of Violence in Prehistoric Southern California. *American Journal of Physical Anthropology* 80:313–323.
1989b The Effects of European Contact on the Health of Alta California Indians. In *Columbian Consequences*, vol. 1, edited by D. H. Thomas, pp. 349–364. Smithsonian Institution Press, Washington, D.C.

Walker, P. L., and P. M. Lambert
1989 Skeletal Evidence for Stress during a Period of Cultural Change in Prehistoric California. In *Advances in Paleopathology*, Proceedings of the VII European Meeting of the Paleopathology Association, edited by L. Capasso, pp. 207–212. Marino Solfanelli, Chieti, Italy.

Wiessner, P.
1982 Risk, Reciprocity, and Social Influence on !Kung San Economics. In *Politics and History in Band Societies*, edited by E. Leacock and R. Lee, pp. 61–84. Cambridge University Press, Cambridge.

Received January 15, 1996; accepted February 14, 1996; revised September 30, 1996.